UNIVERSITY OF ALBERTA LIBRARY
0 0001 8339 960

SD
145
T25
no.0103

SCI

Ex libris
universitatis
albertaensis

S 47-103

CANADA

Department of Forestry

UNIVERSITY OF ALBERTA
AUG 8 - 1961
DOCUMENTS
LIBRARY

ORIGIN AND STRUCTURE OF SOME WHITE SPRUCE STANDS ON THE LOWER PEACE RIVER

by

W. W. Jeffrey

GENERAL SCIENCES

ONE WEEK LOAN

Forest Research Branch
Technical Note No. 103
1961

Published under the authority of
The Honourable Hugh John Flemming, P.C., M.P.,
Minister of Forestry
Ottawa, 1961

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1961

Catalogue No. Fo 47–103

UNIVERSITY
OF ALBERTA LIBRARY

CONTENTS

	Page
Introduction	5
Location and Geomorphology	5
The White Spruce Forest	6
Origin and Structure of the White Spruce Forest	7
Presentation of data	7
Fire	7
Windthrow	8
Vegetational Change	9
Discussion	17
Stand Origin and Structure	17
Silvicultural Significance	19
Summary	19
References	20

94919-8—2

2476933

Origin and Structure of Some White Spruce Stands on the Lower Peace River

by

W. W. Jeffrey[1]

INTRODUCTION

In Wood Buffalo National Park in northeastern Alberta there exists a ubstantial volume of white spruce (*Picea glauca* (Moench) Voss) timber growing n mixture with balsam poplar (*Populus balsamifera* L.) on soils of fluvial origin long the lower Peace River. The existence of this forest has long been known Ogilvie, 1885) but until relatively recent times, commercial utilization of the imber, except for local needs, has been impossible because of its remoteness from he main markets.

Although the area has been subjected to ecological study in the past (Raup, 934, 1946), the recent installation of sawmills, along with the increased tempo f northern development, has stimulated interest in the ecology and management f the forest. The work of Lacate *et al.* (1958) is a result of this intensified research ctivity.

The above work corroborated most of the original conclusions on the forest nd made an important contribution by suggesting that much of the fluvial site hite spruce forest arose following fire, an idea which had not been examined arlier. During an ecological investigation in 1958, the present writer examined he origin and structure of this forest type and his results are the basis of this aper.

LOCATION AND GEOMORPHOLOGY

The area lies along the lower Peace River in northeastern Alberta, approximately at latitude 59°N. and between longitudes 114°40′ and 114°W. It is ocated in the Upper Mackenzie Section, B.23a, of the Boreal Forest Region of anada (Rowe, 1959: 27). Elevation is 600 to 700 feet.

Underlying geological strata consist of Palæozoic rocks of Silurian and evonian age, composed principally of dolomite, limestone and shale (Raup, 946: 22). Over these strata lie glacio-lacustrine deposits of variable and generally indeterminate depth, consisting of sands, silts and clays, usually reddish-rown in colour, laid down by a great post-glacial lake formed at the time of the etreat of the Continental ice sheet (Cameron, 1922 *in* Raup, 1946: 27).

Through this plain of glacio-lacustrine sediments the Peace River has cut meandering course. In this meander zone have been laid down fluvial sediments, rey in colour, rich in lime and organic matter and, from a forestry standpoint, in eneral of much higher potential productivity than the soils of the adjoining lacio-lacustrine plain.

This area of fluvial soil has been termed by the writer "the fluvial deposits andtype". It is with this landtype that this paper is exclusively concerned.

[1] Research Officer, Forest Research Branch, Alberta District Office, Calgary, Alberta.

94919-8—2½

Topography is typical of that formed by fluvial deposition. Low areas of sand and mud bars are commonly present on the inside of meanders. On older fluvial topography a typical point-bar structure is to be found, in which the components are low, rounded ridges (point-bars) with intervening depressions (backswamp deposits). The point-bar landforms are occupied usually by white spruce, balsam poplar-white spruce, or balsam poplar forest, the forest type being largely dependent upon the history of the stand and the soil moisture qualities of the site. The depressions are occupied usually by shrub or meadow cover, though some of the drier swales may support balsam poplar forest.

THE WHITE SPRUCE FOREST

The white spruce forest characteristically occupies the highest and best drained portions of the landtype, being confined largely to the point-bars. According to a limited study by Lacate *et al.* (1958: 37), white spruce reaches a mean dominant height of 120 feet, and its stands attain a mean basal area of 1[illegible] square feet, along with a mean volume of 5,890 cubic feet per acre for stems over 4 inches d.b.h. The maximum standing merchantable cubic foot volume is reached at 190 years and the peak of mean annual merchantable cubic foot increment at 140 years, in the case of even-aged stands (Lacate *et al.* 1958: 37).

Intermixture of balsam poplar is common in the white spruce forest. Usually, however, the proportion of balsam poplar is small, the poplar often appearing to occupy the moister depressions of the topography.

These white spruce stands are predominantly even-aged in character and of regular structure. High density is common in youth but natural loss causes an open canopy and the occurrence of gaps is prevalent in mature and overmature stands.

Dense young stands show a relative absence of secondary vegetation save for cones of *Alnus incana* beneath openings in the canopy. At this stage a moss flora begins to develop, primary species being *Pleurozium schreberi* and *Hylocomium splendens* along with *Ptilium crista-castrensis.*

As the canopy opens through mortality, the minor vegetation increases in luxuriance until, in the overmature stand, woody species are so dense as to impede travel. An underwood composed of *Alnus incana* and *Betula papyrifera*, along with occasional stems of *Amelanchier florida*, becomes general beneath the stand. In the shrub layer *Cornus stolonifera, Rosa acicularis, Viburnum edule,* and *Shepherdia canadensis* are dominant with *Amelanchier florida, Ribes triste, R. lacustre, R. oxyacanthoides, Symphoricarpos albus* and *Lonicera glaucescens* as concomitant species.

In the herb layer dominants comprise *Equisetum pratense, Rubus pubescens, Mitella nuda, Linnaea borealis* var. *americana,* and *Cornus canadensis,* along with *Fragaria glauca, Mertensia paniculata, Pyrola* spp., *Viola renifolia, Viola americana, Galium boreale, Aralia nudicaulis, Ozmorizha obtusa,* and *Lathyrus ochroleucus* as associate species.

The moss layer, which may attain 6 inches in depth, forms an uninterrupted carpet in mature stands. When stand degeneration becomes advanced an influx of light apparently results in decreased vitality of this layer. The moss layer may also be killed by flooding and siltation.

The effects of disturbance on the white spruce forest by fire and cutting have been only partially assessed. Cutting causes an increase in arborescent

shrubs such as *Alnus incana* and balsam poplar root sprouts. The shrub layer also increases, the main species being *Cornus stolonifera*, *Viburnum edule*, and *Rosa acicularis*. After a few years this vegetation becomes very dense and constitutes a closed canopy over the area.

The effects of fire upon the white spruce forest sites are dependent upon the intensity of the burn and have not yet been fully assessed. After a fairly light burn the shrub component soon becomes vigorous, *Epilobium angustifolium* invades in abundance, and *Equisetum pratense* strongly persists. The moss layer disappears. Neither fire nor cutting positively ensure regeneration within a short period.

ORIGIN AND STRUCTURE OF THE WHITE SPRUCE FOREST

Raup (1946) was the first to study the origin of the fluvial site white spruce forest. He recognized that periodic flooding, with attendant siltation and increase in the elevation of land surfaces, over a period of time caused environmental changes which in turn led to modification of the vegetation. He visualized a succession of *Salix* spp.–*Alnus incana*⟶balsam poplar–white spruce⟶white spruce, noting that *Salix Bebbiana* persisted throughout the sere to become a member of the forest flora.

Lacate *et al.* (1958: 20) examined the fluvial site white spruce forest and noted the presence of many signs of past fires. They concluded that "most, if not all, of the productive stands owe their structure to fire history".

The questions of stand origin and structure are important to the silviculturist, since through the first an insight into ecological processes and stand dynamics is found and upon the second are based the practical mechanics of forest treatment.

During the summer of 1958 studies were instituted in these fields. These investigations contained two main phases, the first a broad reconnaissance of the type reported by Lacate *et al.* (1958), the second a series of three detailed studies in which arbitrarily selected small areas were examined to gather data on age structure and stem distribution.

Upon this research it is postulated that the white spruce forest has originated through at least three separate processes: (1) stand removal through fire, (2) stand removal through windthrow, (3) vegetational change from balsam poplar forest.

PRESENTATION OF DATA

Fire

Lacate *et al.* (1958: 19) were first to recognize the importance of fire on the fluvial deposits landtype. As evidence they cited the presence of recent burns, of soil charcoal, burnt snags and fire scars in maturing stands, of soil charcoal in overmature stands, the general occurrence of even-aged structure, and the presence of soil charcoal at depth in the old fluvial deposits.

The broad phase of this investigation had as its purpose the collection of general information similar to that given above. The results of this phase, in the main, followed the conclusions listed above. The evidence of past burning is very clear. Soil charcoal and burned soil layers occur at depth in many areas. Burned wood may be found beneath up-rooted stems and beneath the roots of living trees. Beneath some stands soil charcoal at shallow depths can be uncovered almost

everywhere. Burned snags and stumps may be found in almost all young stan Recent burns, some of large extent, occur upon the landtype. Even-aged structu appears to be prevalent.

Windthrow

A stand believed to originate from windthrow was given intensive study i plot of one-half acre on a moist site. Soil moisture, greater in the slight pressions, had resulted in a concentration of white spruce on the higher are with balsam poplar, *Salix* spp., and *Alnus incana* in the wetter spots. This mic site mosaic is common in the spruce stands of the landtype.

Structure was regular, unistoreyed, 60 to 90 feet in canopy height and 6 to inches in d.b.h., mean d.b.h. being 10 inches.

The effect of natural mortality was evident in moss-covered fallen timb which has resulted in an irregular, hummocky forest floor. The dominant m was *Hylocomium splendens* with *Ptilium crista-castrensis* and *Pleurozium schreb* as associates. In the herb layers *Mitella nuda, Equisetum pratense, Rubus pubesce* and *Cornus canadensis* were the main species while the shrub layer w dominated by *Alnus incana* and *Viburnum edule.*

Examination of a soil pit showed the following profile.

Horizon	*Depth (inches)*	*Material*
1	0—3½	litter and live moss
2	3½—9	very fine sandy silt
3	9—14	rotted white spruce log
4	14—17	very fine sandy silt
5	17—27	rotted white spruce log
6	27—30	very fine sandy silt
7	30—40	very fine sandy silt and silty very fine sand saturat with water
	40	*frozen ground* (August 29, 1958)

In assessing the age structure of the one-half acre plot the ages[2] of 110 of the 1 white spruce occurring on the area were determined.

Of the 110 stems of determinable age, nine were less than 100 years, 88 we 101 to 130 years, 11 were 131 to 160 years, and two were older than 200 yea These values have been expressed graphically in Figure 1. All stems young than 100 years may be considered part of the main stand establishment. T youngest stem had an age of 80 years. Stems older than 140 years must be consi ered as pre-existent to the main stand. Three stems enter this category, t oldest being 248 years old, an indication that the area carried spruce at least 1 years prior to the establishment of the matrix of the present stand.

Further examination of the stand structure is possible through Figure This figure shows that spatial distribution by age class is not heterogeneou The older trees tend to be concentrated in a group in the northeast portion of t plot. Stems less than 100 years old appear to occur close to gaps in the sta Spacing between stems is very variable.

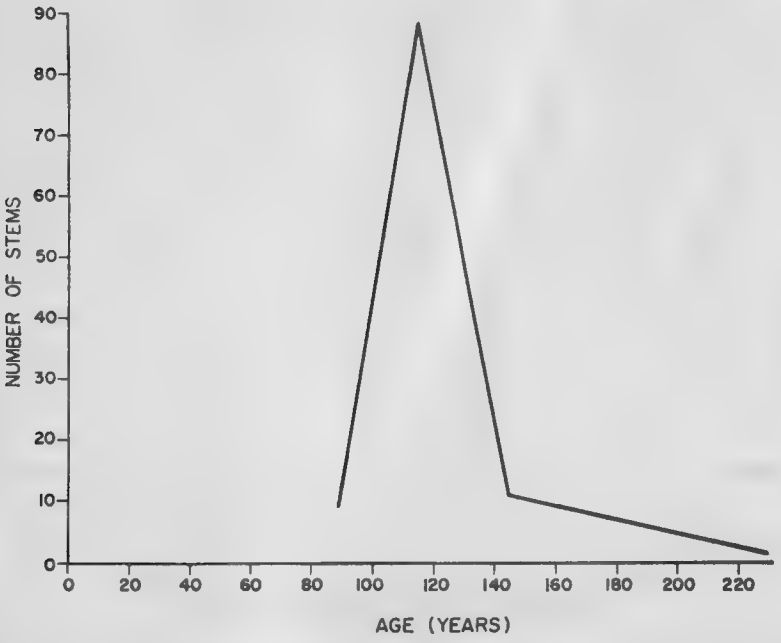
[2] Ages were taken at stump height (ten inches above ground level). Counts were made from increment cores of stand trees and directly from the stump on cut-over areas. As noted by Jeffrey (1959: 310), stem burial by sediment deposi results in stem age being a relative rather than an absolute value.

A notable feature is the orientation of groups of trees in markedly straight lines, which strongly suggests an origin on decayed wood, the lines representing fallen stems.

Recapitulating the stand history from the analyses of Figures 1 and 2, it is probable that an abrupt change in environment occurred at some time prior to 140 years ago. Such a change in environment is strongly suggestive of catastrophe, acting upon a previous stand of white spruce, known to have been present from the presence of old trees and the abundance of buried spruce wood in the soil. An exhaustive search was made for soil charcoal and other signs of burning but none

FIGURE 1

STEM DISTRIBUTION BY AGE CLASSES



were uncovered. Excavation established beyond doubt, however, that the upper layer of the soil was rich in buried spruce wood and that many of the existing spruce had rooted in this decayed wood.

The above evidence strongly suggests that the catastrophe which overtook the previous stand was windthrow.

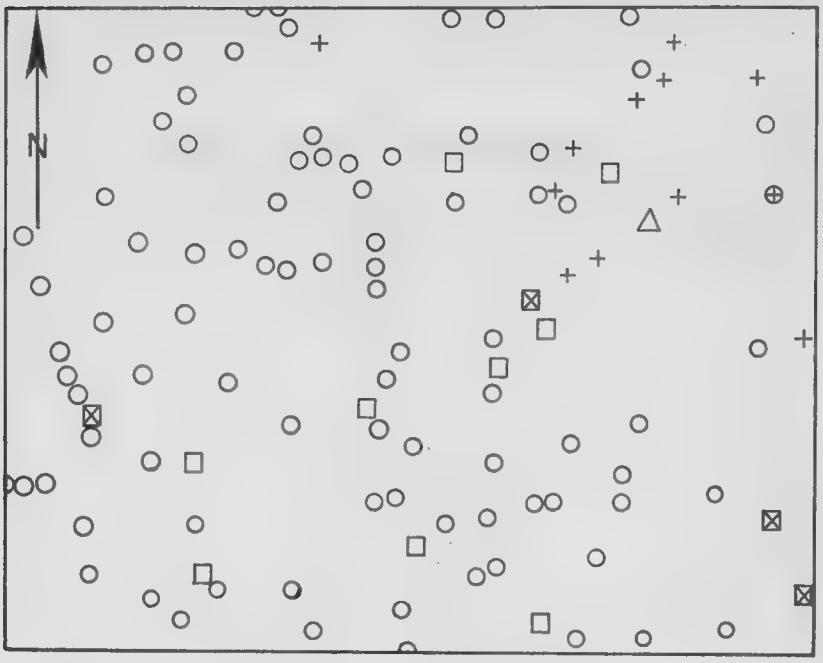
Vegetational Change

Raup (1946: 46) postulated a successional process by which the white spruce forest developed from *Salix* spp. through balsam poplar–*Alnus incana* forest to white spruce–balsam poplar forest and finally to white spruce forest with concomitant balsam poplar. Lacate *et al.* (1958: 19) verified this succession but thought it confined to "the most recent alluvial deposits". On fluvial sites of the

FIGURE 2

SPATIAL DISTRIBUTION OF STEMS

AND AGE STRUCTURE OF STAND OF WINDFALL ORIGIN



LEGEND

AGE

Indefinite		⊠
Under 100	years	□
101—130	years	○
131—160	years	+
161—190	years	Nil
191—220	years	△
Over 220	years	⊕

lower Liard River area the writer has seen this succession in progress and believes it to be the main mode of origin of the white spruce–balsam poplar forest on those sites in that area.

Stands originating through succession are believed to be more irregular in structure and more uneven-aged than stands originating following catastrophe. For this reason a two-acre sample of the stand of greatest irregularity of structure encountered was subjected to intensive examination.

An unusually wide range in d.b.h., 1 inch to 26 inches, was a character of the stand. The stand matrix was white spruce with occasional balsam poplar and white birch. The stand was in process of breakdown, the forest floor being littered with dead wood, and gaps being present in the canopy. Stocking was very variable from one small area to the next.

An underwood of *Alnus incana* and white birch was present, over-topping a high shrub layer of *Cornus stolonifera, Viburnum edule, Rosa acicularis, Alnus incana, Ribes oxyacanthoides,* and *R. lacustre.* The dominant species of the herb layer were *Equisetum pratense, Aralia nudicaulis,* and *Mitella nuda.* In the moss layer, which formed a discontinuous mosaic, *Hylocomium splendens, Ptilium crista-castrensis, Pleurozium schreberi, Dicranum rugosum,* and *Brachythecium* spp. were to be found. The site was moderately moist, the soil being typical fluvial very fine sandy silt containing buried organic layers.

A d.b.h. tally was made of 319 white spruce growing on an area of approximately two acres. Species other than spruce were not tallied. Results of this tally are given in Table 1.

TABLE 1. D.B.H. TALLY OF WHITE SPRUCE ON TWO ACRES

D.b.h. Class (inches)	D.b.h. Range Within Class (inches)	No. of Stems
2	0.6 — 3.5	57
5	3.6 — 6.5	38
8	6.6 — 9.5	27
11	9.6 — 12.5	42
14	12.6 — 15.5	49
17	15.6 — 18.5	62
20	18.6 — 21.5	36
23	21.6 — 24.5	6
26	24.6 +	2

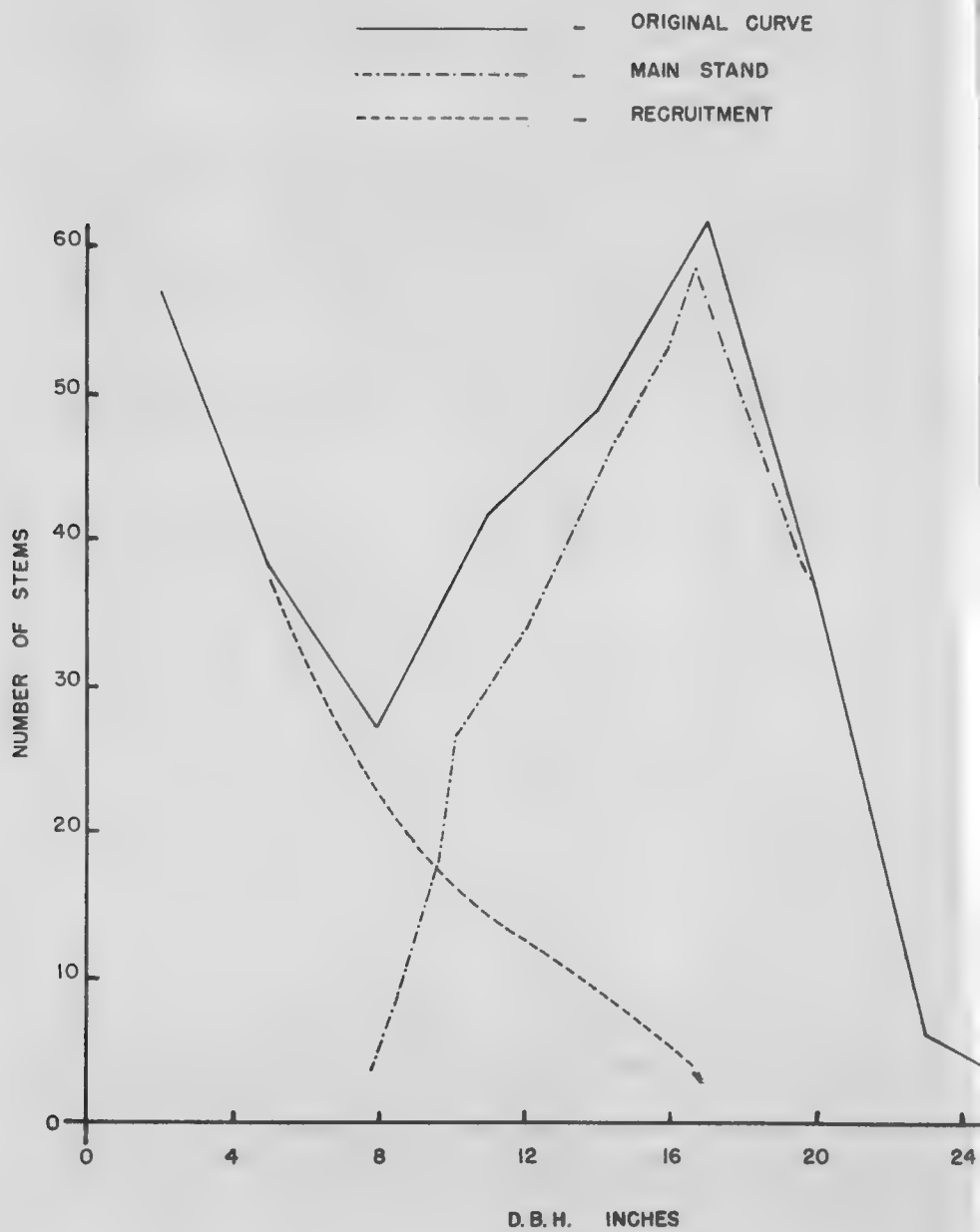
The values in Table 1 have been expressed graphically in Figure 3. Between the 8 and 23 inches d.b.h. classes, a Gaussian form of curve is shown. Between the 2 and 8 inches d.b.h. classes an arcuate form of curve occurs. Thus, the stand structure may be termed "partially irregular". This structure may have resulted from a recruitment of young growth into a stand of basically regular structure. The interrupted lines in Figure 3 are theoretical expressions of these two stand components, the recruitment (arcuate curve) and the original growing stock (Gaussian curve).

FIGURE 3

STEM NUMBER CURVE

SHOWING

DIAMETER DISTRIBUTION BY THREE–INCH SIZE CLASSES



In this stand a plot 100 feet by 50 feet was charted. This plot carried 28 stems of which 2 were white birch and the remainder white spruce. Age of the white spruce varied between 75 and 242 years. Age and d.b.h. structure of the white spruce are given in Table 2.

TABLE 2. AGE AND D.B.H. OF 26 WHITE SPRUCE ON SMALL PLOT

Age Class (years)	No. of Stems	Mean D.b.h. (inches)
Under 100	5	2.8
101 — 130	9	8.2
131 — 160	5	11.7
161 — 190	2	15.6
191 — 220	1	19.0
Over 220	4	15.8

Spatial distribution of stems on the plot is shown in Figures 4 and 5. Prominent gaps exist and stem distribution varies from isolated stems to closed groups. The most prominent group is that formed by stems 6, 9, 10, 11, 12 and 13, which range in age between 116 and 139 years. Heights in the group range from 25 to 117 feet and d.b.h. between 2.9 and 16.0 inches. Thus the group qualified for "even-aged" classification at the same time as being "irregular", an obvious ambiguity in terminology.

On the plot, 67 seedlings, of which 66 were growing on decayed wood (*see* Rowe, 1955: 6-7), were discovered, the sole exception being rooted in moss and humus.

Height and age data collected are summarized in Table 3.

TABLE 3. AGE AND HEIGHT OF 66 SEEDLINGS ON SMALL PLOT

Age (years)	Total Number	NUMBER OF SEEDLINGS								
		Height Classes (inches)								
		4–5	6–7	8–9	10–11	12–13	14–15	16–17	18–19	20+
5	2	2								
6	3	1	1	1						
7	5	2	2	1						
8	11	1	3	5	2					
9	14		6	3	1	3		1		1 (20″)
10	15	2	1	3	4	3	1		1	
11	5		1	1	3					
12	4					2	1	1		
13	3					2		1		
14	Nil									
15	Nil									
16	1								1	1 (22″)
17	1								1	1 (20″)
18	1								1	1 (26″)
19	1								1	1 (23″)

It is noteworthy that no trees of age between 19 and 75 years existed on the plot. This may indicate the difficulties of securing lasting and adequate spruce regeneration under white spruce stands.

FIGURE 4

HORIZONTAL PROJECTION OF CROWN COVER
and
SPATIAL DISTRIBUTION OF STEMS

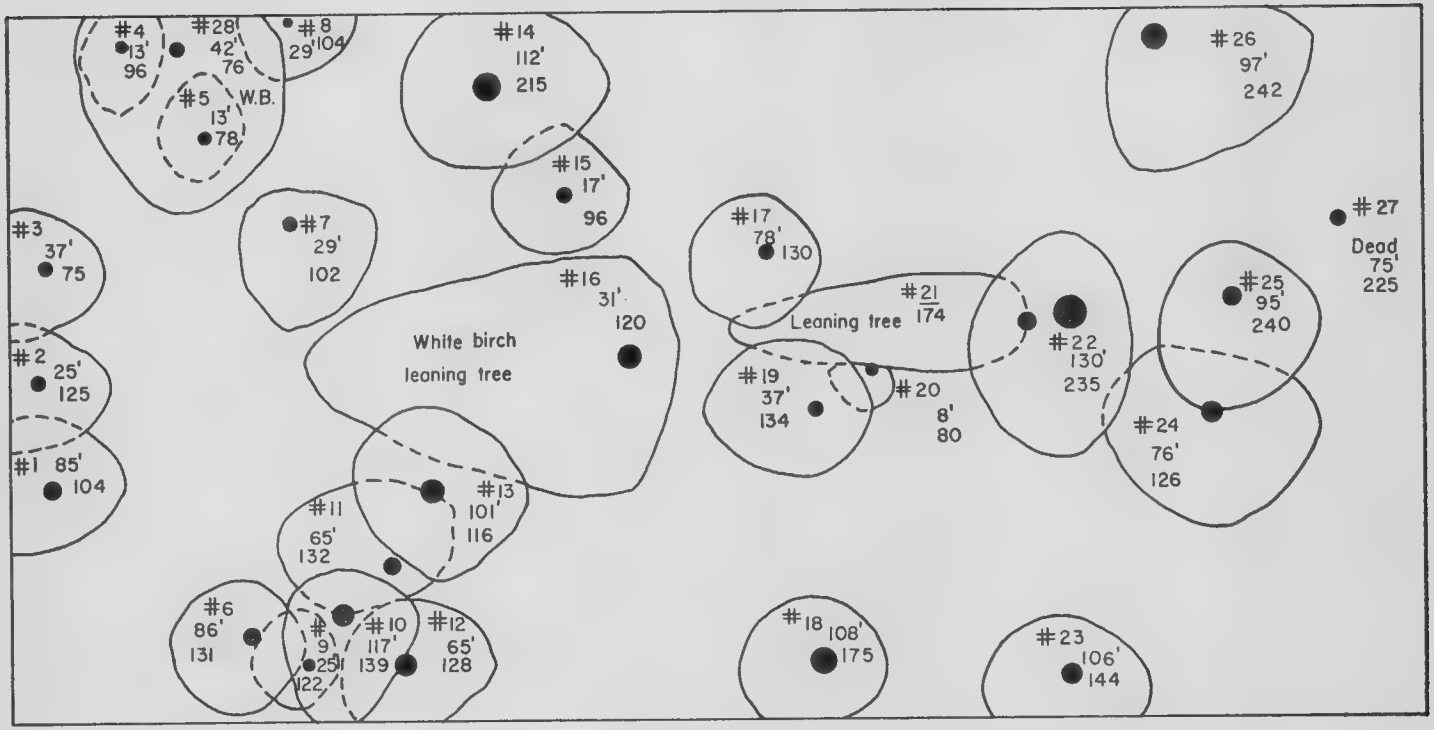
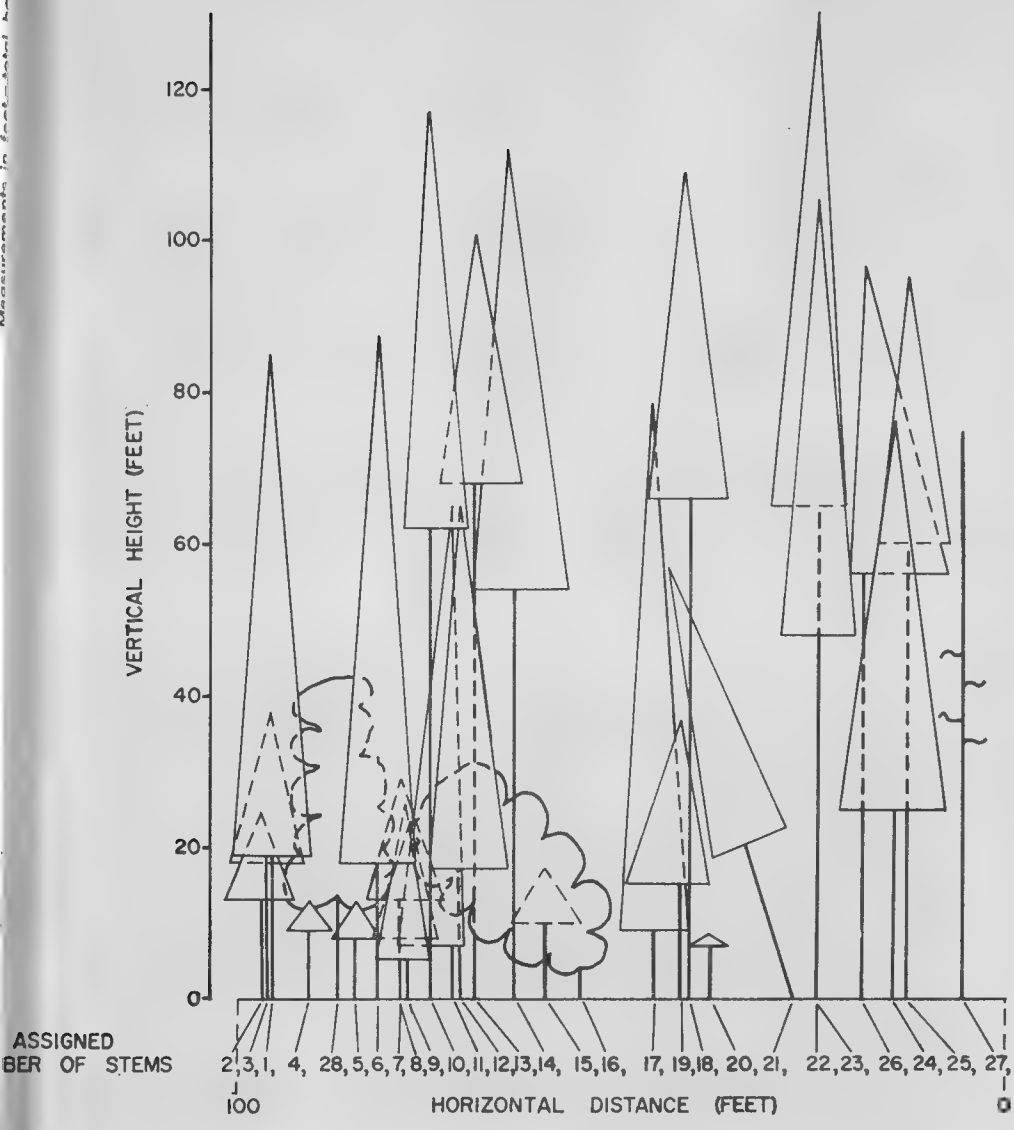


FIGURE 5

PROFILE SKETCH OF TREE LAYERS



LEGEND

Unobscured Crown.....△

Obscured Crown.....△

The openness of this stand and its degree of irregularity make it unusual o this landtype. Excavation of buried balsam poplar wood, some of which wa found beneath tree roots, along with the uneven-aged structure, tends to indicat origin by vegetational change, through gradual replacement of a pre-existen balsam poplar stand. From the stem data in Figure 4, no consistency in height age or diameter/age relationships emerges on an individual tree basis. This i due to the demonstrated ability of white spruce, once established, to withstan suppression for long periods, during which growth may be practically arrested.

A second area studied had been logged over, so that no stand descriptio can be given. White spruce constituted the matrix of the stand with occasiona balsam poplars interspersed. Bands of willow-alder shrub association occurred i slight depressions.

The area was sampled with a one-acre plot, in which the soil was a very fin sandy silt with strata of buried organic matter. Of 115 spruce stems on the plot the ages of 100 were determinable. These ages are grouped in Table 4.

TABLE 4. AGE DISTRIBUTION OF 100 WHITE SPRUCE ON ONE-ACRE PLOT

Age Class (years)	No. of Stem
Under 100	4
101 — 130	14
131 — 160	18
161 — 190	24
191 — 220	38
Over 220	2

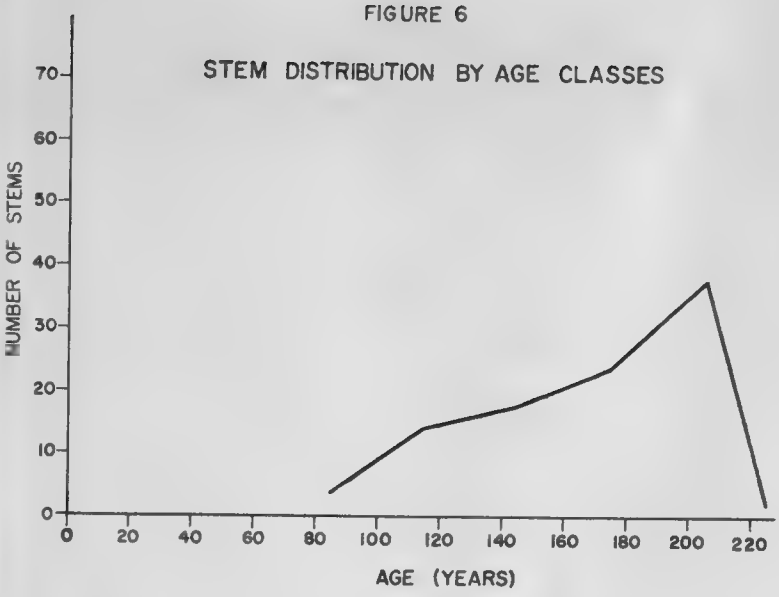
Age Class 191—220 years shows the highest representation. The number o trees in the younger age classes becomes progressively smaller. One may assum that a higher proportion of the older age classes has been lost through mortality so that the curve may have tended to flatten with time. Stem frequency/ag is plotted in Figure 6.

A plan of the area is given in Figure 7. The occurrence of gaps is immediatel evident. Grouping by age classes is poorly defined, there being only one well marked group, namely that of trees 131 to 160 years old on the centre-north boundary. In addition, there is a limited concentration of stems less than 16 years old in the northeast portion. Most of the stems uniformly distributed ove the area are between 161 and 220 years old, the age class comprising the matri of the stand.

Despite intensive search no charcoal or other sign of fire was found on the area. Excavation revealed, however, that decayed balsam poplar wood and bar were present beneath almost half of the trees examined, whereas no white spruce wood was found in this situation.

From the age structure of the stand it would appear that prior to 220 years ago the area was occupied by a stand of balsam poplar. At this time conditions became favourable for white spruce growth, probably as the result of degeneration of the balsam poplar stand. Establishment of spruce proceeded with diminishing incidence until 100 years ago when it practically ceased altogether.

FIGURE 6



From the data presented, it is apparent that a proportion of the overmature hite spruce stands on fluvial sites has originated by undisturbed vegetational ıange from pre-existent balsam poplar stands. Such areas may be recognizable ŗ the range in age and the irregularity of the stand structure.

DISCUSSION

:and Origin and Structure

Upon the evidence presented it is postulated that three modes of origin are ssible: (1) fire, (2) windfall, and (3) vegetational change.

Care must be taken to place the past occurrence of fire in the proper context. he effect of fire upon vegetation depends upon the intensity of the burn. vere ground fire often results in a seral vegetation markedly different from that llowing a mild crown fire (Rowe, 1955). In the fluvial site white spruce forest e apparent preference of the white spruce seedling for mineral soil (Rowe, 1955; ace, 1955), in relation to the heavy cover of moss and organic matter, may use the *type* of fire to be of greater importance than the *fact* of fire *per se*.

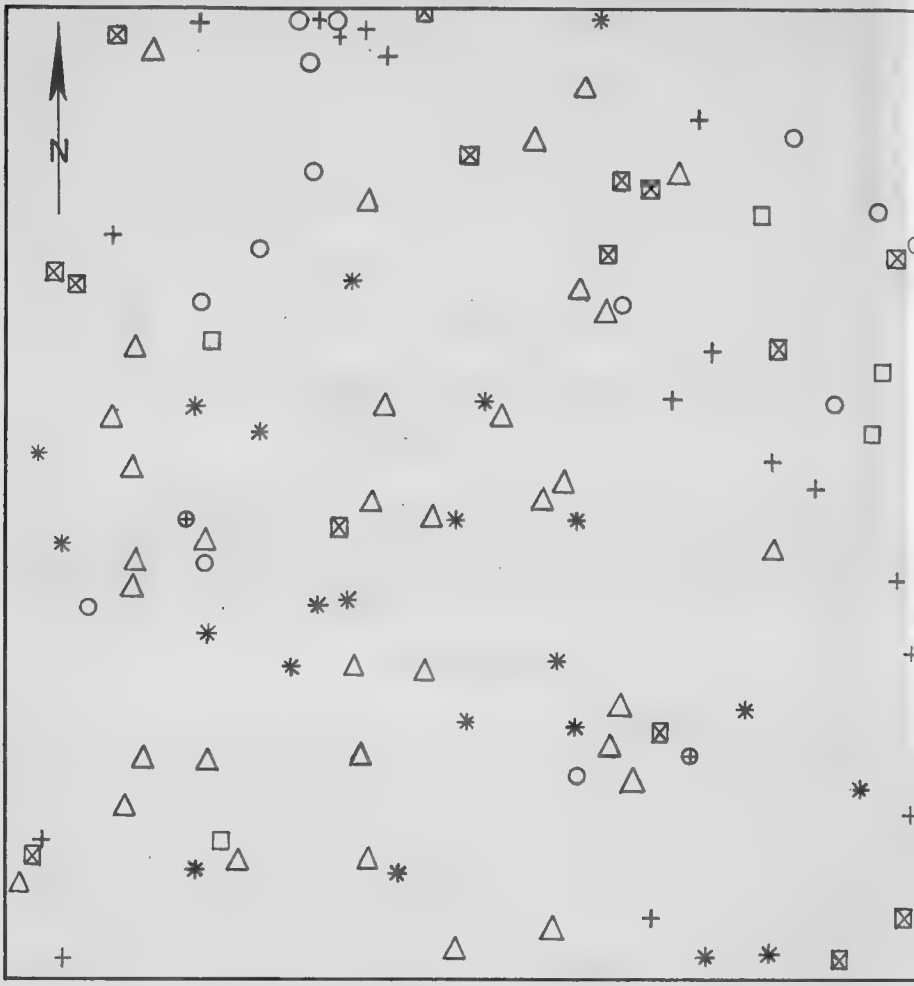
Fire normally functions as a removal agency though not always does it act a regenerative agency (Rowe, 1955: 19). With regard to these separate roles fire (removal and regenerative), the influence of periodic flooding and deposition ay be important and the deposition of a sediment layer during periodic flooding ay be the agency of regeneration rather than the fire itself.

While the occurrence of soil charcoal at depth is supporting evidence for the eory of "fire origin", it cannot always be regarded as a significant influence uring the history of the present white spruce forest. The presence of charcoal the soil at shallow depths is a strong base for a hypothesis of fire origin, and here it occurs in abundance there can be little reasonable doubt that establish-

FIGURE 7

SPATIAL DISTRIBUTION OF STEMS

AND AGE STRUCTURE OF STAND OF SUCCESSIONAL ORIGIN



ent of the present stand was preceded by fire.[3] As noted by Lacate *et al.* (1958:), this tends to be most common in younger stands. There can be little question en that many, probably most, of the younger stands on the landtype arose lowing removal of a pre-existent cover by fire, either with or without the ditional stimulus of sediment deposition.

While the maturing stands of the landtype are believed to have originated lowing catastrophe, and probably in the main after fire, the evidence for edominant fire origin in the overmature stands, which form the larger proortion of the growing stock (Lacate *et al.* 1958: 29), cannot be regarded at this ne as being completely conclusive. There is no doubt that many of these stands iginated following the removal of a pre-existent cover by fire, but the magnitude that proportion must at the present time remain problematical.

White spruce on the fluvial deposits landtype, owing to adventitious rooting imulated by periodic deposition of sediment in flooding (Jeffrey, 1959), tend to deep and windfirm. Extensive windthrow is not believed to be common, though acate *et al.* (1958: 20) mention a stand believed to be of windfall origin, and the ta previously presented indicate that "windfall origin" cannot be ignored.

It is probable, therefore, for the above reasons that windfall origin is not as equent in its incidence as "fire origin". Wherever a stand of regular structure curs upon a station lacking in signs of fire history, the possibility of windfall igin must be considered.

Some overmature stands are believed to have originated through a process vegetational change. The data presented indicate, by irregularity of vertical ructure and wide range in stem age, that such a progress is operative. While is succession is not confined to the most recent fluvial deposits as Lacate *et al.* 958: 19) have suggested, from the evidence of stands demonstrating a degree irregularity it would appear that it is not so general a succession as originally pposed.

lvicultural Significance

From the evidence gathered in the fluvial site white spruce forest it is appart that this species regenerates best following catastrophe. Thus it would appear at systems of partial cutting are not advisable in the white spruce forest, though peculiar resistance to windthrow (Jeffrey, 1959) might make such systems asible.

A majority of the stands are regular in structure. Where irregularity exists, general it is not pronounced. Clear cutting in mature stands is therefore unely to result in troublesome standing residual material.

Recommended treatment therefore is clear cutting by strips or patches, companied where necessary by scarification or controlled burning to provide ineral soil.

SUMMARY

This Technical Note reports on studies of origin and structure in fluvial site hite spruce forest, and gives a summary of previous work.

The spruce forest is believed largely to have arisen following fire, with windll and vegetational change as other modes of origin. A high proportion of stands

[3] The possibility was recognized that soil charcoal and buried wood might have been deposited by floodwaters on ndated land. For this reason both materials have been cited as evidence only when present in quantity.

presently immature have a fire history. Undisturbed vegetational cha (primary succession) has possibly been of relatively greater importance in o stands.

The forest is composed primarily of regular, even-aged stands, thoug places some degree of irregularity does exist.

Tentative silvicultural recommendations comprise clear cutting by st or patches, accompanied where necessary by scarification or controlled burn

REFERENCES

CAMERON, A. E. 1922. Post glacial lakes in the Mackenzie River Basin, North West Territo Canada. Jour. Geol. 30: 337-353.

JEFFREY, W. W. 1959. White spruce rooting modifications on the fluvial deposits of the lo Peace River. For. Chron. 35(4): 304-311.

LACATE, D. S., K. W. HORTON and A. W. BLYTH. 1958. Forest conditions on the lower P River. Canada, Dept. of Northern Affairs and National Resources, For. Res. D S. and M. 58-8.

OGILVIE, W. 1885. Athabaska and Peace Rivers. Canada, Dept. of Interior, Annual Report 1884. Sess. Paper No. 13. Pt. 2.

PLACE, I. C. M. 1955. The influence of seed-bed conditions on the regeneration of spruce balsam fir. Canada, Dept. of Northern Affairs and National Resources, Forestry Bra Bull. 117.

RAUP, H. M. 1934. Botanical investigations in Wood Buffalo Park. National Museum of Can Bull. 74.

RAUP, H. M. 1946. Phytogeographic studies in the Athabaska–Great Slave Lake Region. J Arnold Arbor. Vol. XXVII: 1-78.

ROWE, J. S. 1955. Factors influencing white spruce reproduction in Manitoba and Saskatche Canada, Dept. of Northern Affairs and National Resources, For. Res. Div., T Note No. 3.

ROWE, J. S. 1959. Forest regions of Canada. Canada, Dept. of Northern Affairs and Nati Resources, Forestry Branch, Bull. 123.

SD 145 T25 NO-0103
JEFFREY W W
ORIGIN AND STRUCTURE OF SOME
WHITE SPRUCE STANDS ON THE
39852586 SCI

000018339960

DATE DUE SLIP

FEB 02 RETURN

FEB 02 RETURN

Due Cam MAR 07 '93

Due Cam MAR 21 '93

MAR 19 RETURN

Due Cam APR 09 '96

APR 10 RETURN

NOV 28 RETURN

RETURN JAN 02 '01

F255